Research article

Ultrasonic measurement of rectal diameter and area in neurogenic bowel with spinal cord injury

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Objective: The aim of this study was to determine the efficacy of measuring the diameter and area of the rectum using ultrasonography as an additional parameter for the evaluation of neurogenic bowel in patients with spinal cord injury (SCI).
Participants: In total, 32 patients with SCI (16 patients with upper motor neuron neurogenic bowel (UMNB) and 16 patients with lower motor neuron neurogenic bowel (LMNB)) participated in this study. We divided the patients by the type of neurogenic bowel: UMNB, patients with supraconal lesions and recovery state of spinal shock or LMNB, patients with infraconal/caudal lesions or spinal shock state).
Intervention: Ultrasound was applied on the abdomen and measured the diameter and area of the rectum were measured twice each before and after defecation, respectively.
Outcome measure: We compared rectal diameter and area before/after defecation between the two groups, and significant differences were found in both rectal diameter and area before/after defecation in each group.
Results: After defecation, those in the UMNB group had smaller rectal diameters and areas than those in the LMNB group. Significant reduction of rectal diameter and area was observed after defecation as well. The LMNB group showed slightly increased rectal area after defecation, but the increase was not statistically significant.
Conclusion: Using ultrasound to measure rectal diameter and area seems helpful for classifying neurogenic bowel types and for understanding the neurogenic bowel among SCI patients with symptoms of neurogenic bowel.

Keywords: Ultrasonography, Rectum, Neurogenic bowel, Spinal cord injuries

Introduction

Neurogenic bowel is one of the most common sequelae of SCI (spinal cord injury). Among the symptoms of neurogenic bowel, constipation, fecal incontinence and abdominal pain affect as high as 41–81% of patients with SCI.[1–4] These patients take extensive drugs as well as digital stimulation and manual evacuation to relieve the symptoms of neurogenic bowel, but many still suffer from refractory constipation.[2–7] Neurogenic bowel interferes with early rehabilitation and also affects the physical and psychological well being as well as the quality of life of patients with chronic SCI.[3–6]

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Neurogenic bowel can be categorized as either upper motor neuron neurogenic bowel (UMNB) or lower motor neuron neurogenic bowel (LMNB). The former occurs in those with a spinal cord lesion above the conus medullaris and is referred to as a spastic bowel due to an excessive increase in the tone of the bowel wall and anus. LMNB, on the other hand, is referred to as flaccid bowel. The flaccid bowel has weak movement of the bowel wall because of injury to the parasympathetic cell bodies in the conus or axons of the cauda equina and is accompanied by slow stool propulsion by the myenteric plexus rather than spinal cord-mediated reflex peristalsis.[5,8]

There are only limited number of tests to assess neurogenic bowel in patients with SCI, including bowel diary, digital rectal examination, neurogenic bowel dysfunction (NBD) score, abdominal X-ray, colonic transit

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time test, anorectal manometry, and the balloon expulsion test.[9–14] Several recent reports measured rectal diameter using ultrasound. Joensson *et al.*[15] used ultrasound to measure rectal diameter in children with or without constipation. Karaman *et al.*[16] measured the mean rectal diameter by ultrasound for diagnosis and follow-up of children with constipation. Both of these studies found that the mean rectal diameter was significantly greater in children with constipation and reported that measuring rectal diameter by ultrasound would be a valuable test for diagnosing constipation. Bijoś *et al.*[17] used ultrasound in children with functional constipation and found that the width of the rectal ampulla in children with constipation was greater than that in those without constipation; their results were highly associated with proctoscopy and colon transit time.

Thus far, ultrasound has not been used to evaluate the type of neurogenic bowel in patients with SCI.[15–17] The aim of our study was to determine whether the efficacy of ultrasonography measurement of rectal diameter and area could be applied to identify spinal cord injuries with neurogenic bowel, and to show whether there are differences in rectal diameter and area measurement between patients with UMNB and LMNB.

Materials and methods

Patients

We enrolled 32 patients with SCI in our study who were hospitalized in the Rehabilitation Department at Chonbuk National University Hospital. The inclusion criteria were patients with acute SCI who were transferred to the Department of Rehabilitation Medicine after acute treatment without bowel habit change within the last week and patients with chronic spinal cord injury. The exclusion criteria were patients who missed follow-up examinations and patients with conus medullaris lesions showing combined with both UMNB and LMNB. The 32 patients were divided into an UMNB group and a LMNB group. The UMNB group consisted of 16 patients who had lesions above the conus medullaris and with positive bulbocavernosus (BC) reflex or ice water tests (IWT) in the bladder. The LMNB group consisted of 16 patients who had lesions below the conus medullaris or at the cauda equine or patients who had not recovered from spinal shock and who had negative BC reflex and IWT in the bladder.[7,8,18–20] The type of SCI was classified according to the International Standards for Neurological Classification of SCI (Revised 2011).[21] This study was approved by the institutional review boards at our institution.

Methods

The age, height, body weight, body mass index, and injury duration of each patient was determined and recorded. The type of SCI was classified according to International Standards for Neurological Classification of SCI (Revised 2011). To classify the neurogenic bowel type, spasticity, BC reflex, and the IWT in the bladder were examined. To determine the functional ability and defecation severity of each patient with SCI, spinal cord independence measure-III (SCIM-III) and NBD score were assessed. The NBD score is composed of 10 items, including the frequency of bowel movement, time used for defecation, headache and perspiration of discomfort before or at defecation, tablets against constipation, drops against constipation, frequency of digital stimulation or evacuation, frequency of fecal incontinence, medication against fecal incontinence, flatus incontinence, and perianal skin problems.[22]

Ultrasonography (Sonoace9900 prime®, Medison, Hongchun, Korea) was used with a 5–7 MHz convex probe with patients lying comfortably in the supine position. The probe was placed 2 cm above the pubic symphysis, inclined downward by 10–15° to measure the area where the rectal area was the largest.[17] In order to confirm the accurate location of the rectum, a rectal tube was inserted to a few patients with unclear rectal boundaries by ultrasonography (Fig. 1). On average, the location of the rectum was 10–13 cm from the anal verge. At the transaxial plane, the largest area in the rectum was selected and measured by drawing the outer border of the rectum at the selected level.[23,24] The rectal diameter was measured at the level with the longest transverse diameter within the rectal area.[15–17]

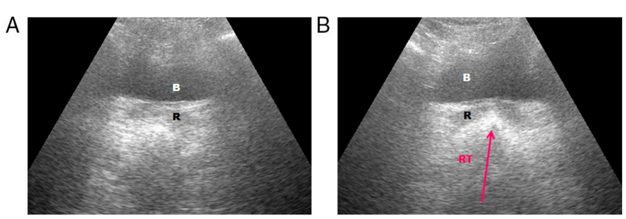

Figure 1 Rectal tube insertion in rectum: (A) Before rectal tube insertion (B) After rectal tube insertion. Abbreviations: B, Bladder; R, Rectum; RT, Rectal tube.

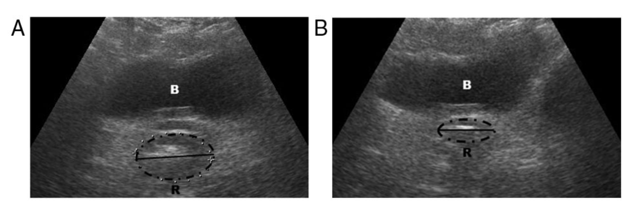

Figure 2 Measurement of rectal transverse diameter and area before (A) and after defecation (B). Abbreviations: B, Bladder; R, Rectum.

Table 1 Baseline demographics

		UMNB	LMNB
Number	Male	12	11
	Female	4	5
	Total	16	16
Age		63.4 ± 12.7	47.9 ± 13.9*
Level of injury	Cervical	16	8
	Thoracic	0	4
	Lumbar	0	4
ASIA impairment scale	A	1	6
	B	0	1
	C	2	1
	D	13	8
Days after injury		132.7 ± 178.6	44.7 ± 49.5
Height		164.6 ± 10.8	167.4 ± 6.4
Weight		63.9 ± 12.1	64.1 ± 8.9
BMI		23.5 ± 3.0	22.9 ± 3.5
NBD score (total)		7.5 ± 8.4	13.9 ± 5.4*
SCIM-III		51.8 ± 19.2	46.4 ± 30.5

Abbreviation: UMNB, Upper motor neuron neurogenic bowel; LMNB, Lower motor neuron neurogenic bowel; ASIA, American spinal injury association; BMI, Body mass index; NBD, Neurogenic bowel dysfunction; SCIM, Spinal cord independence measure.
*P < 0.05, Comparison between the UMNB and LMNB groups.

The measurement of the rectal diameter and area was performed twice within 2 hours before defecation (Fig. 2A) and within 1 hour after defecation (Fig. 2B), respectively. After measurement, the mean value from the two measurements was calculated. The operator of the ultrasonography was blinded to the neurological condition of the patients.

Statistical analyses

SPSS version 18.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Age, height, body weight, NBD score, SCIM-III, rectal diameter and area before/after defecation were compared between UMNB and LMNB groups by independent *t*-test, while differences in rectal diameter and area before/after defecation within two group were analyzed using the paired *t*-test. P values < 0.05 were considered statistically significant. Based on the ultrasound findings, the sensitivity, specificity, positive predictive value and negative predictive value for the rectal area and diameter were assessed and compared.

Results

Demographic data

A total of 32 patients with SCI were included in our analysis, with 16 (male 12 and female 4) in the UMNB group and 16 (male 11 and female 5) in the LMNB group. The patients in the LMNB group had higher total NBD scores and were younger in age than those in the UMNB group (P = 0.001) (Table 1).

Rectal diameter

The mean rectal diameters in the UMNB group were 4.49 ± 0.62 cm before defecation and 4.01 ± 0.54 cm after defection (P = 0.023), and the mean rectal diameters in the LMNB group were 4.75 ± 0.79 cm before defecation and 4.69 ± 0.98 cm after defecation (P = 0.735). Rectal diameter was significantly reduced after defecation in the UMNB group but not in the LMNB group. In a comparison of the two groups, patients in the UMNB group had a significantly smaller mean rectal diameter than those in the LMNB group after defecation (P = 0.022). However, there were no significant differences in rectal diameter between the two groups before defecation (P = 0.313) (Table 2).

Rectal area

The mean rectal area before defecation was 4.27 ± 1.69 cm² in the UMNB group and 4.80 ± 2.44 cm² in the LMNB group, showing no significant difference

Table 2 Rectal diameter, area, and change rates before and after defecation

	UMNB	LMNB
Mean RD (cm) before defecation	4.49 ± 0.62	4.75 ± 0.79
Mean RD (cm) after defecation	4.01 ± 0.54*†	4.69 ± 0.98
Mean RA (cm^2) before defecation	4.27 ± 1.69	4.80 ± 2.44
Mean RA (cm^2) after defecation	2.79 ± 1.50*†	4.95 ± 2.39

Abbreviation: RD, Rectal diameter; RA, Rectal area; UMNB, Upper motor neuron neurogenic bowel; LMNB, Lower motor neuron neurogenic bowel.
*By paired *t*-test, P < 0.05.
†By independent *t*-test, P < 0.05.

between the groups ($P = 0.479$). After defecation, however, rectal area in the UMNB group reduced to $2.79 \pm 1.50\ cm^2$ compared to $4.95 \pm 2.39\ cm^2$ in the LMNB group, which was significantly different between the groups ($P = 0.005$). The UMNB group patients had a significant reduction in rectal area after defecation ($P = 0.001$), but the LMNB group showed a slight increase in rectal area after defecation, but the difference was not significant ($P = 0.636$) (Table 2).

Sensitivity, specificity and predictive values of rectal ultrasonography in UMNB patients

In the UMNB group, negative changes in the rectal diameter and area were considered positive outcome. In the LMNB group, positive changes in rectal diameter and area were considered positive outcome. The sensitivity, specificity, positive and negative predictive values were assessed for comparison. The sensitivity, specificity, positive predictive value and negative predictive value in the rectal diameter were 93.75, 37.50, 60.00 and 85.71%, respectively. The sensitivity, specificity, positive predictive value and negative predictive value in the rectal area were 87.50, 62.50, 70.00 and 83.33%, respectively (Table 3).

Table 3 Sensitivity, specificity and predictive values of rectal ultrasonography in UMNB patients

	Diameter (%)	Area (%)
Sensitivity	93.75	87.50
Specificity	37.50	62.50
Positive predictive value	60.00	70.00
Negative predictive value	85.71	83.33

Discussion

Constipation in patients with SCI can be categorized as UMNB type or LMNB type. The former accompanies overactive segmental peristalsis in the bowel, but the external anal sphincter (EAS), which should be normal under voluntary control, becomes tightened due to a spastic pelvic floor, causing fecal retention in the colon. In these cases, since constipation is caused by fecal retention, mechanical or chemical stimulation needs to be applied to induce the recto-colic reflex. Constipation in the patient with LMNB arises from slow peristalsis and continuous water intake, making the feces thicker and more rounded. In these cases, the EAS remains relaxed without innervation, increasing the risk of fecal incontinence.[5,8]

An accurate standard for dividing the UMNB from the LMNB has not yet been established. Previous studies either classified supraconal lesions as UMNB and conal or cauda equine lesions as LMNB. Tsai *et al.* and Yim *et al.*[7,8] used the presence of spinal sacral reflex (BC reflex) as the basis for classification. Using the level of anatomical lesions among patients with complete thoracic and lumbar spinal cord injuries, Doherty *et al.*[18] reported that the T7–T9 group had 85.5% upper motor neuron lesions, while in the T10–T12 group, 17.7% of lesions were upper motor neuron lesion, 57% were lower motor neuron lesions, and 25.3% were mixed lesions. In the L1–L3 group 95.5% were lower motor neuron lesions. In our study, conus medullaris lesions were excluded as they often accompany mixed lesions. In addition, the BC reflex and IWT in the bladder were added for assessing the condition of spinal shock state. Regardless of the lesion location, patients with spinal shock state (negative BC reflex and IWT in bladder) were classified as LMNB. Dividing the neurogenic bowel by the anatomical lesion and the presence or absence of spinal shock state more accurately demonstrated the differences in the diameter and area of the rectum after defecation than classification of the neurogenic bowel according to only anatomical lesion or only the presence and absence of BC reflex and IWT in the bladder.

Constipation is a common symptom among patients with SCI, but there are few tools to evaluate it. Plain abdominal radiography is widely used as a constipation test, but its value as a diagnostic tool has recently been reported as below expectations.[9,10,12] It is also possible to measure colon transit times using either radiopaque markers or radioisotopes.[10,12,25] The area under the curve (AUC) was shown to be 0.90 (95% CI, 0.83–0.96), suggesting superiority of colon transit time as a diagnostic tool.[10] However, this method is time-consuming, not comfortable for patients, and does not allow bowel management during the test period. Anorectal manometry, which determines bowel dysfunction by evaluating the condition of the rectum and the anus, is especially valuable in obtaining information from patients with evacuation disorders. However, anorectal manometry has not yet been established by accurate methods and standards of measurement.[12,13] Finally, in the balloon expulsion test, this is also a limited test considering posture problems and absence of anal and rectal tone in many patients with SCI.[12,14] Taken together, there are several tests that can be applied to patients with SCI, but none of them are good enough.

Using ultrasound for bowel evaluation was introduced relatively recently. Berger *et al.*[10] found that the rectal diameter of children with constipation was greater than that of healthy children. A rectal diameter cut-off value of 3.3 cm was used in their study, and any size reported that was greater than 3.4 cm indicated constipation.

The AUC of 0.847 (95% CI, 0.790–0.904) also suggests considerable diagnostic value.[10,26] Rectal diameter testing by ultrasound is noninvasive, does not require irradiation, and has potential diagnostic value for diagnosis and management of constipation, but evidence on its diagnostic value is still not sufficient.[10]

Most of the previous ultrasonography studies on constipation compared differences in rectal diameter between children with constipation and control groups.[15–17] To our knowledge, none of the previous studies used ultrasound to evaluate neurogenic bowel type in patients with SCI.

In most of the patients in our study, the average location of the rectum was 10–13 cm from the anal verge. Memon *et al*.[27] measured anterior peritoneal reflection (the location of the anterior peritoneal reflection represents the location of the rectum[28]) for preoperative radiotherapy and reported the average location as 11.9 and 10 cm from the anal verge, for men and women, respectively, which is comparable to the location of the rectum measured in our study. In addition to rectal transverse diameter, we compared rectal area by ultrasonography to evaluate the neurogenic bowel in patients with SCI. Gynecologic methods used for measuring the umbilical cord in pregnant women were used for measuring rectal area.[23,24] In the UMNB group, the sensitivity, specificity, positive predictive value and negative predictive value were compared between the rectal diameter and area. The rectal area showed higher values in specificity and positive predictive value compared to the diameter.

After defecation, patients in the UMNB group had significantly smaller rectal diameters and areas than those in the LMNB group. On the other hand, the LMNB group showed slightly increased rectal areas after defecation, but the difference was not significant ($P = 0.636$). We suppose that patients with LMNB showed inefficient defecation when compared to patients with UMNB. More specifically, it may be implied that only the feces in the lower rectum of patients with LMNB were defecated, and the fecal material in the upper rectum was left stagnant, or even increased in volume, as reflected in ultrasonography.

The total NBD score was higher in the LMNB group than in the UMNB group, possibly suggesting that patients with LMNB have more difficulty in defecation.

The major the limitation of this study is the small sample size. More studies on ultrasonography for measuring rectal diameter and area should be performed using a larger group of patients with SCI to further investigate the usefulness and diagnostic value of ultrasound for neurogenic bowel classification.

Conclusion

In our current study, we used ultrasound to measure rectal diameter and area in patients with SCI with symptoms of neurogenic bowel and found that rectal diameters and areas after defecation were smaller in patients with UMNB as compared to patients with LMNB. Patients with UMNB also had significantly smaller rectal diameters and areas after defecation than before defecation. Our results suggest that rectal measurement by ultrasound before and after defecation may be helpful for classifying neurogenic bowel type and for understanding neurogenic bowel problems among patients with SCI with symptoms of neurogenic bowel.

Disclaimer statements

Contributors (1) GWK MD – ultrasonic measurement of rectum, writing paper; (2) YHW, MD – revision of the paper (3); JHS, MD, PhD – first direction, corresponding author; (4, 5) MHK, MD, PhD and SHP, MD, PhD – secondary direction.

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Conflicts of interest None.

Ethics approval This study was approved by the institutional review boards at our institution.

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